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INNOVATIVE FLOTATION FOR THE BENEFICIATION
OF
EASTERN CANADIAN COALS
USING AN
AIR SPARGED HYDROCYCLONE

MICROMEDIA

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57 pp

Abstract

A project funded by the Federal Government of Canada investigated the Air Sparged Hydrocyclone for flotation cleaning of coal. The Air Sparged Hydrocyclone offers the prospect of high rate treatment and high efficiency in the particle size range of 400 mesh. For this project, Prince coal from Nova Scotia (approximately 18 % ash, 4 % S) was ground to 80 % - 100 mesh and slurried at 7 % solids for flotation. A three inch diameter unit was operated at rates up to 133 litres per minute.

The results obtained were promising. One three inch diameter unit achieved acceptable flotation cleaning at the rate of 15 tonnes per day, with strong indications that better results at higher rates are possible. Further work to optimize the flow rate and other cyclone parameters would seem well justified.

Résumé

Le gouvernement fédéral du Canada a financé un projet pour examiner l'effet d'un hydrocyclone pulvérisé à l'air pour le nettoyage du charbon par flottaison. L'Hydrocyclone représente une possibilité de traiter le charbon à une haute vitesse et à haut rendement pour les particules de 400 mailles de grosseur. Ce projet a été exécuté avec du charbon Prince de la Nouvelle Ecosse (teneur approximative de 18% en cendre et 4% en soufre), 80% de l'échantillon a été meulé à 100 mailles et la schlamm avait 7% de solides pour la flottaison. Un hydrocyclone avec un diamètre de trois pouces a été utilisé pour éprouver l'échantillon jusqu'à une capacité de 133 litres par minute.

Les résultats obtenus par les essais étaient prometteur. L'unité de trois pouces en diamètre a atteint une capacité acceptable de 15 tonnes par jour de flottation avec des indications que de meilleurs résultats à plus haute capacité sont possible. De plus ample recherche sont recommandés pour acquérir une condition optimum de la capacité et autre paramètres du cyclone.

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Conclusions and Recommendations

- 1) Successful flotation cleaning of Prince coal was achieved using a three inch diameter Air Sparged Hydrocyclone. Seven percent solids slurries of nominal - 100 mesh particles were treated at rates up to 133 l/min.. Since the results at 133 l/min. were as good as any others obtained, it is assumed that even higher rates would be possible.
- 2) Air Sparged Hydrocyclone flotation required roughly twice as much collector and one and a half times as much frother as conventional bench flotation.
- 3) For these conditions, air flow to slurry flow ratios of about three were required.
- 4) The bench flotation response was not very sensitive to flotation conditions provided that sufficient frother and collector were employed. This conclusion was confirmed in the pilot operation.
- 5) Cleaning efficiency with the Air Sparged Hydrocyclone was not quite as good as predicted by the bench work. In a tailing of 25 % by weight, bench products contained 69 % of the ash compared with 62 % of the ash for the pilot plant work.
- 6) Incremental reagent addition and concentrate removal was beneficial in the bench work. Air Sparged Hydrocyclone performance might also be enhanced if done in two or three stages instead of one.
- 7) Unexpectedly, a most critical relationship is between the slurry flow rate and the size of the underflow annulus opening. This relationship was not adequately explored during these tests, but indications are that optimization would result in significant benefit.

Conclusions and Recommendations (cont'd)

- 8) Evaluation of potential capital savings due to the high treatment rate per unit volume of the Air Sparged Hydrocyclone is beyond the scope of this project. But any such evaluation must include an assessment of the wear characteristics of the porous sleeve in continuous duty. In this project the unit was not operated long enough to generate any noticeable wear, but coal slurries are abrasive.
- 9) Further study of the Air Sparged Hydrocyclone is warranted. Ideally, a unit similar to or slightly larger than the pilot unit should be set up in an operating plant to run in parallel with conventional flotation. This would permit a detailed assessment of the operating parameters and the wear characteristics without imposing the burden of large sample preparation and handling.

Introduction

Mineral flotation using an Air Sparged Hydrocyclone is described by J.D. Miller et al in several papers dating to about 1980. The concept employs a standard cyclone header to create a swirling film of slurry. The cyclone body is replaced by a porous sleeve through which air is sparged. The myriad micro-bubbles so produced contact slurry particles in the film zone. Bubble loading is achieved at a very high rate. The froth exits via the cyclone overflow while the tailing slurry reports to the underflow. Because the retention (and flotation) time is a matter of seconds, the slurry must be fully pre-conditioned.

Reported advantages of this system over conventional flotation include lower capital and improved selectivity in the finer sizes.

An unsolicited proposal was made to the Government of Canada, Department of Supply and Services, to test this concept for cleaning eastern Canadian coal. Contract 04SQ/23440-5-9227 was awarded in May, 1986 and work was begun immediately.

The actual testwork and analyses were performed at and by the Research and Productivity Council in Fredericton, New Brunswick.

Scope of Work

Because of budget constraints, the scope of this work was necessarily limited to testing one coal source with one reagent schedule. The most important test parameters were judged to be slurry flow rate, air flow rate and reagent level.

Scope of Work (cont'd)

Initially, just enough bench work was done to select a coal and a workable reagent schedule to provide a comparison marker for the pilot plant work.

Using the bench work results and published information on the operational characteristics of the Air Sparged Hydrocyclone, several preliminary pilot tests were conducted to establish basic practicable conditions. Around those conditions, a factorial experiment was designed to evaluate their relative significance.

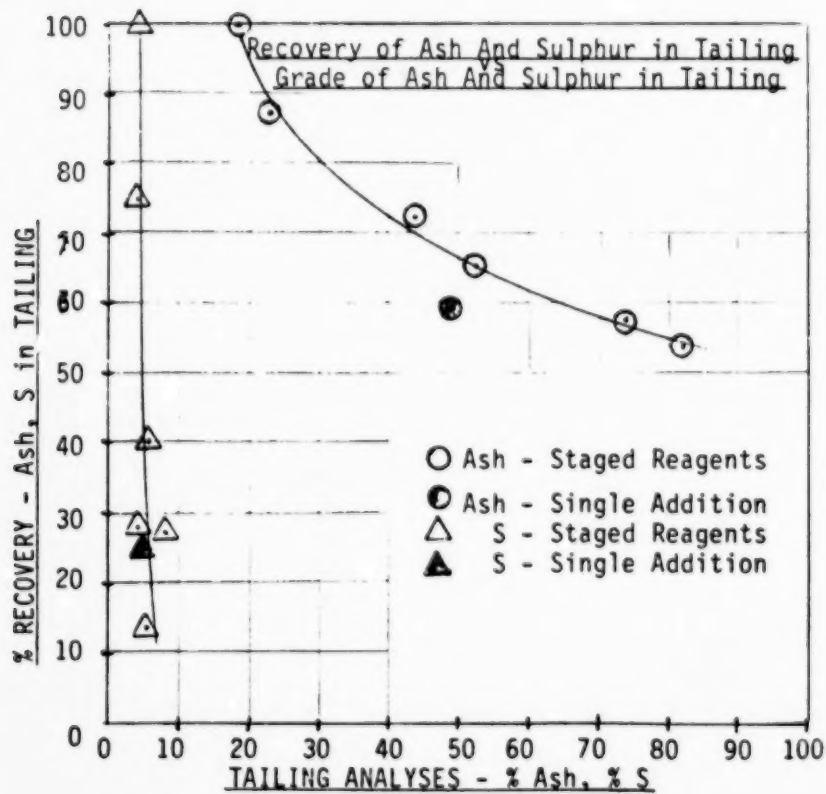
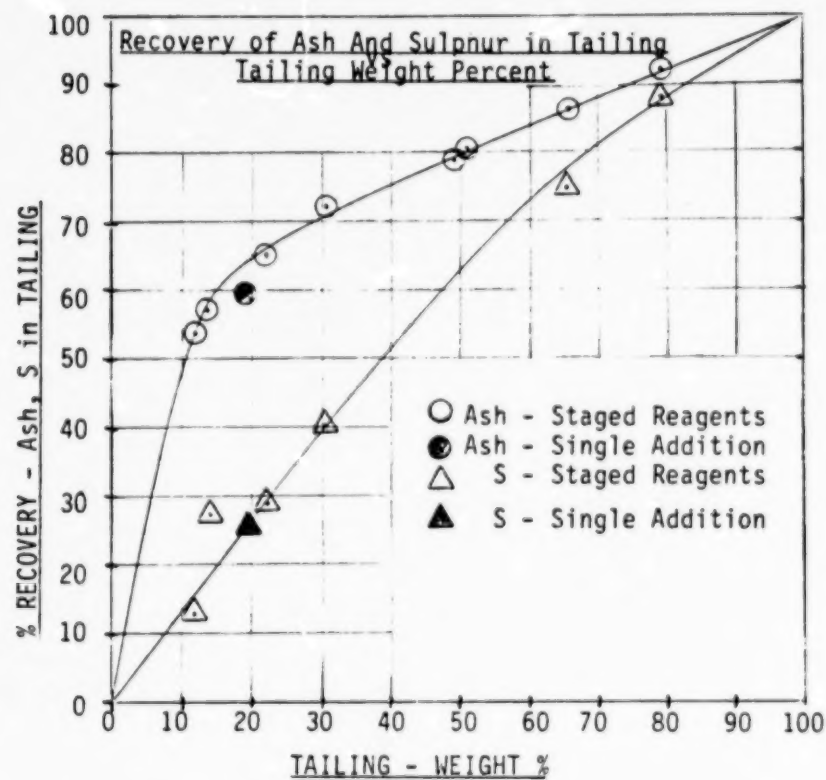
The objective of the project was not to optimize a flowsheet for a particular coal but rather to estimate the validity of an Air Sparged Hydrocyclone compared with conventional flotation equipment.

Bench Work and Sample Selection

Two samples readily available for this work were Minto coal from New Brunswick and Prince (Devco) coal from Nova Scotia. Since flotation is primarily applied to coal fines and because the cyclone discharge annulus would be small (approximately 1 mm) a nominal - 100 mesh grind was recommended.

Screen analyses for the actual grinds done and bench work details are given in Appendix I. Both samples required frother (MIBC) and collector (Kerosene) to achieve good flotation. No other reagents were tried. The bench tests, performed at 7 % solids, included incremental reagent and concentrate removal, simple conditioning and pre-aeration. All of the results were remarkably consistent, showing little or no sensitivity to any

FIGURE 1

BENCH WORK ON PRINCE COAL

Bench Work and Sample Selection (cont'd)

variables except reagent dosage and time. Minto coal did not demonstrate any significant selectivity for either ash or sulphur removal. Prince coal was not much better with respect to sulphur but did permit reasonable ash rejection with a recognizable break in the rejection curve. Therefore, Prince coal was selected for the pilot investigation with the following base conditions:

Grind - 80 % -100 mesh

MIBC - 250 g/tonne

Kerosene - 630 g/tonne

Sample Preparation

Nominal $-1\frac{1}{2}$ + 1 inch coal was reduced to - 100 mesh in stages using: a Denver 2 1/4 x 3 1/2 inch crusher; a Massco XL6 cone crusher; a Bico UA pulverizer; a Spaleck PC-2 Vibra Finish ball mill. All of the reduction was performed dry. The Vibra Finish mill was charged with 36 lbs. of steel balls for 25 lb. batches of coal.

The 25 lb. batches were immediately bagged and stored in a freezer unit at -20° F to minimize oxidation. When roughly 600 lbs. cumulative had been prepared, the bags were removed from the freezer, emptied onto the floor for shovel mixing, rebagged and returned to the freezer.

Air Sparged Hydrocyclone Design

Previously reported coal cleaning experiments with an Air Sparged Hydrocyclone passed 66 USGPM (250 l/min.) through a 6 inch diameter unit. At that feed rate, sample handling would be an economic and physical hardship. Assuming that the capacity of a cyclone would be roughly proportional to the square of the diameter, a 3 inch diameter unit was chosen to treat 16 USGPM (60 l/min.).

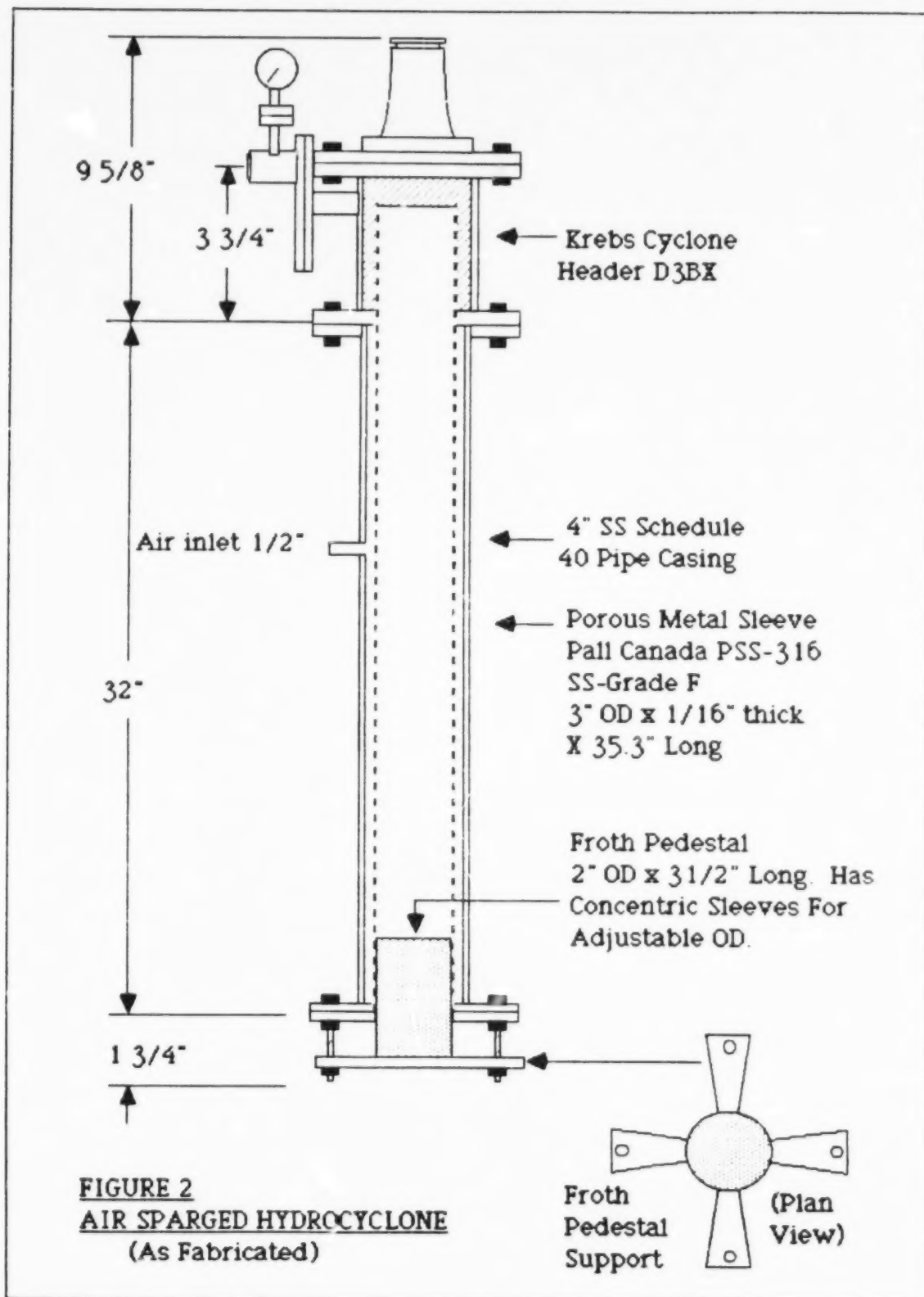
Components purchased or fabricated were:

- a Krebs 3 inch diameter cyclone header Model D3BX
complete with liner and having : inlet ID = 1 inch;
vortex finder ID = 3/4 inch.
- a stainless steel sintered metal porous sleeve from
Pall Canada, 3 inch OD x 35.5 inches long and having:
wall thickness of 1/16 inch; average pore size of 5
microns.
- a froth pedestal of adjustable diameter.
- a stainless steel body casing of schedule 40 pipe

The assembled hydrocyclone is shown in Figure 2 and Appendix III holds photographs of the various components.

Test Circuit Design

Bench work indicated the type of flotation products to be expected. The froth would be voluminous and persistent while the tailing, carrying most of the clay and slime would be difficult to clarify or filter. The overriding criterion would be sample handling. Because the contact time



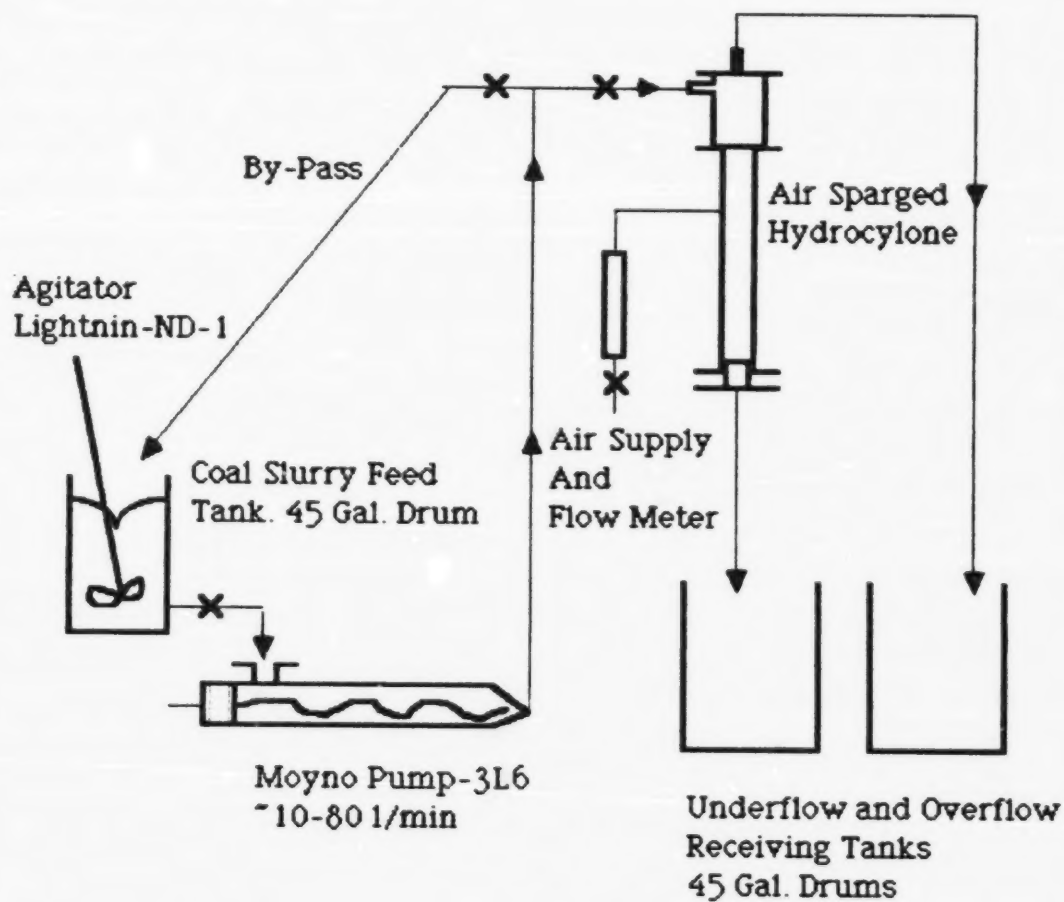
Test Circuit Design (cont'd)

in the cyclone is very short (2 - 3 seconds) and because the circuit would have no recycle features, stable conditions would be achieved in less than ten seconds. It would be feasible to perform a test with a feed duration of about 90 seconds, permitting the feed and product receiving tanks to be 45 gallon drums for easy handling.

The remaining equipment consisted of:

- a Lightnin' ND-1 mixer
- a Moyno 3L6 variable speed pump (10 - 80 l/min.)
- a compressed air source
- a Brooks air flow meter
- miscellaneous piping and valves

The equipment was arranged as shown in Figure 3. Later in the programme, to permit the testing of higher feed rates, a GSW pump driven by a Briggs and Stratton 3 hp engine was obtained. The nominal specification for that pump was 118 USGPM against a 20 foot head.



X - Valve

FIGURE 3

AIR SPARGED HYDROCYCLONE
DIAGRAMATIC TEST CIRCUIT

Preliminary Test Work and Factorial Design

Initial operating experience with the pilot circuit developed a practicable procedure as follows:

- i - the feed tank was filled with tap water to approximately 139.5 litres.
- ii - with the feed tank agitator running, dry crushed coal in the amount of 10.5 kg was added and allowed to wet for five minutes.
- iii - the feed pump was started, recycling back to the feed tank while the rate was adjusted and a head sample obtained. The reagents were added and conditioned for five minutes.
- iv - the cyclone air was pre-set to the desired level.
- v - the valve to the cyclone feed line was opened and the recycle valve closed.
- vi - after ten seconds, the entire overflow and underflow were diverted to five gallon sample pails. For a feed rate of 57 l/min. the sample time was 20 seconds; for 76 l/min., 15 seconds.
- vii - at the end of the first sample period, the air flow rate was adjusted to a second setting and a second set of samples taken as in vi.

Thus from 10.5 kg of coal, two tests were performed in an elapsed time of 15 minutes. For each sample of underflow and overflow, the following procedure applied:

- i - the entire slurry sample was weighed.
- ii - the volume of slurry was estimated (because the froth was so persistent, the reported volume of slurry was not very accurate).
- iii - the sample solids were filtered out on No.4 Whatman filter paper and the samples dried at approximately 95°C.

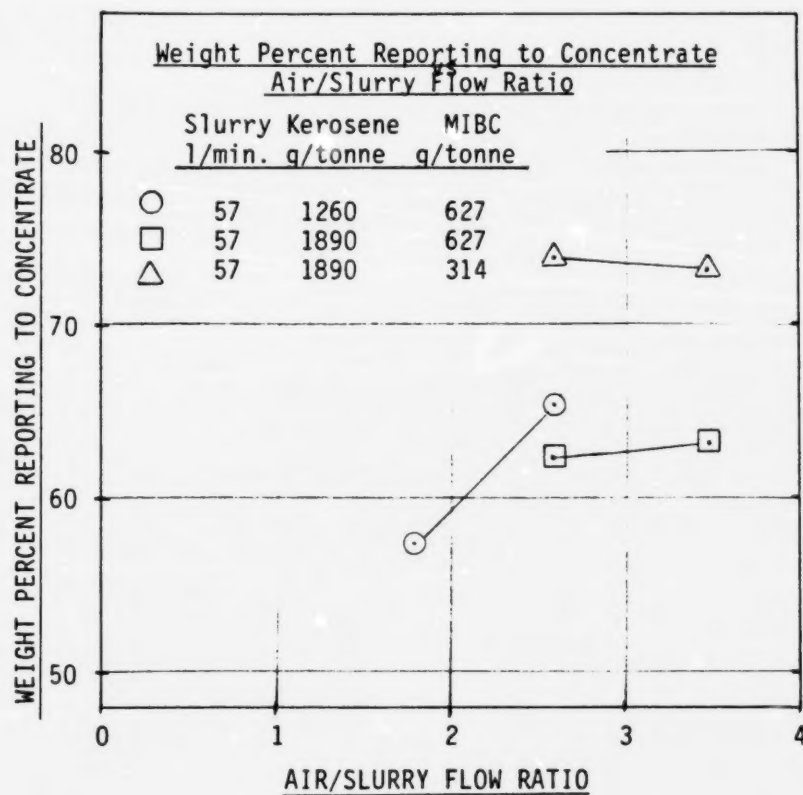
Preliminary Test Work and Factorial Design (cont'd)

This procedure had a basic weakness in that the sample weights and volumes over such short sample periods were subject to considerable error. However, because the cyclone operated at such a high rate, even the short sample periods resulted in volumetrically large samples. Due to the clay and slime content, these were slow to process. Samples from the two tests performed in fifteen minutes took the next three hours to prepare for drying. While larger samples would have given more accurate results, the project budget would not have survived the handling requirements.

The test parameters for tests 5,6 and 7 were selected using the bench results and the generalized conditions reported for Air Sparged Hydrocyclone performance. That is, reagent dosage about double that required for conventional flotation and air flow 2 to 4 times the slurry flow. The results of those tests are shown in Table 2. In Figure 4, air to slurry ratio is plotted against concentrate weight recovery for three different reagent conditions. These results indicated that with an air to slurry ratio between 3 and 4, Kerosene between 1260 and 1890 g/tonne and MIBC between 314 and 627 g/tonne some combination should achieve an adequate concentrate recovery. Accordingly, the factorial parameters were fixed as follows:

- | | |
|--------------------|--|
| Slurry Flow : | i - 57 l/min. |
| | ii - 76 l/min. |
| Air/Slurry Ratio : | i - 3 |
| | ii - 4 |
| Reagents : | i - Kerosene @ 1500 g/tonne
MIBC @ 313 g/tonne |
| | ii - Kerosene @ 1320 g/tonne
MIBC @ 543 g/tonne |

FIGURE 4

PILOT PLANT PRELIMINARY RESULTS - TESTS 5,6,7

Preliminary Test Work and Factorial Design (cont'd)

Since the results of these tests indicated a distinct separation of data between tests at 57 l/min. and those at 76 l/min., additional test were added at 133 l/min. :

Slurry Flow : iii - 133 l/min.

Air/Slurry
Ratio : i - 3

ii - 4

Reagents : i - Kerosene @ 1500 g/tonne
 MIBC @ 313 g/tonne

iii - Kerosene @ 1000 g/tonne
 MIBC @ 313 g/tonne

At the flow rates tested the cyclone pressure drops were:

Slurry Flow l/min	Pressure psig
57	1-2
76	4-5
133	10-12

Experimental Results

The experimental conditions and results are displayed in Tables 1 and 2. Recovery of Ash in Tailing is plotted against Weight Percent of Tailing in Figures 5 and 6. Figure 5 is a small scale plot so that the comparison of laboratory to pilot results stands out. In Figure 6, the scale is larger to better demonstrate the relationship of the individual tests to each other. In Figure 7, the results for sulphur are plotted in similar fashion. Sulphur rejection was non-selective in the pilot tests just as predicted by the bench work.

None of the pilot tests were quite as good as the best bench work (solid line in Figures 5 and 6). But the best bench work results were generated with incremental reagent addition and incremental concentrate removal. Note that the best pilot results were very close to the bench results obtained with single reagent addition.

Increasing the slurry flow rate from 57 l/min. to 76 l/min. had a beneficial effect on the flotation performance. Referring to Figure 6, compare Tests 10 and 12 (57 l/min) with Tests 9 and 11 (76 l/min.). Between 76 and 132 l/min. the trend was not duplicated. Compare Tests 9 and 11 (76 l/min.) and Test 13 (132 l/min.). However, the similarity of these tests could be related to the annulus opening as described under Discussion of Results.

Increasing the air flow to slurry ratio had the general effect of increasing concentrate recovery - without changing the selectivity - for the lower slurry flow rates of 57 and 76 l/min.. Compare Tests 9 to 12 A with Tests 9 to 12 B. At the highest slurry flow rate, 132 L/min.,

TABLE 1
Test Conditions and Slurry Data
Pilot Plant Tests

TEST No.	Date 1986	PURPOSE	FEED PREPARATION AND TEST PARAMETERS					MEASURED SLURRY DATA								
			Feed Rate l/min	Slurry Ratio	Air to Slurry Ratio	Kerosene g/tonne	Reagents MIBC g/tonne	Rate l/min	Feed Slurry % solids	pH	Rate l/min	Conc. Slurry % solids	pH	Tailing Slurry Rate l/min	% solids	pH
5 A	Sept.	Preliminary	57	1.8	100	1260	627	42.8	6.6	12.0	13.6	30.8	3.9	30.8	3.9	
B			57	2.6	150	1260	627	60	6.7	24.0	10.5	36.0	3.9	36.0	3.9	
6 A			57	2.6	1890	627	48	6.4	16.5	12.3	31.5	3.6	31.5	3.6		
B			57	3.5	1890	627	48	6.5	21.0	9.8	27.0	4.1	27.0	4.1		
7 A			57	2.6	150	1890	314	48	6.2	15.0	15.4	33.0	2.3	33.0	2.3	
B			57	3.5	200	1890	314	48	6.2	19.5	12.2	28.5	2.6	28.5	2.6	
8 A			57	2.6	150	1800	628	44.4	3.7	3	18.6	41.4	2.6	41.4	2.6	
B			57	3.5	200	1800	628	44.4	3.4	7.2	7.0	6.7	37.2	2.5	37.2	2.5
9 A		Factorial	76	3.0	227	1500	313	70	6.4	5.7	22.0	13.3	5.2	48.0	3.5	5.7
B			76	4.0	302	1500	313	70	6.5	5.7	18.0	20.9	5.1	52.0	2.2	5.7
10A			57	3.0	170	1500	313	48	6.6	5.3	16.5	15.0	5.8	31.5	2.7	6.0
B			57	4.0	227	1500	313	48	6.5	5.3	21.0	11.2	5.4	27.0	3.1	5.6
11A			76	3.0	227	1320	543	64	6.6	5.0	24.0	10.4	5.0	40.0	4.3	5.8
B			76	4.0	302	1320	543	64	6.4	5.0	28.0	8.9	5.9	36.0	4.6	5.7
12A			57	3.0	170	1320	543	48	6.5	6.3	21.0	11.1	6.0	27.0	3.5	6.4
B			57	4.0	227	1320	543	48	6.2	6.3	27.0	6.9	6.0	21.0	5.3	6.3
9AD	Nov.	Factorial	76	3.0	227	1500	313	66	6.0	14.0	21.4	5.7	52.0	2.4	5.2	
BD			76	4.0	302	1500	313	66	6.0	14.0	18.4	5.7	52.0	2.5	5.1	
10AD			57	3.0	170	1500	313	48	5.9	10.5	17.5	6.1	37.5	2.5	6.0	
BD			57	4.0	227	1500	313	46.5	5.9	10.5	17.0	5.8	36.0	2.6	5.1	
11AD			76	3.0	227	1320	543	64	6.1	16.0	19.9	5.2	48.0	2.0	5.9	
BD			76	4.0	302	1320	543	64	5.8	16.0	17.9	5.2	48.0	1.8	5.2	
12AD			57	3.0	170	1320	543	46.5	5.0	12.0	16.1	6.1	34.5	2.4	6.0	
BD			57	4.0	227	1320	543	46.5	7.2	13.5	18.6	6.4	33.0	2.6	6.5	
13 A	Dec.	Higher Rate	132.5	3.0	397	1500	313	127.5	6.4	37.5	15.8	90.0	2.2	90.0	2.2	
B			132.5	4.0	520	1500	313	117.8	6.5	33.8	14.3	84.0	3.0	84.0	3.0	
14 A			132.5	3.0	397	1000	313	138.8	6.8	71.3	10.5	67.5	3.2	67.5	3.2	
BD			132.5	4.0	520	1000	313	112.4	6.6	56.2	9.9	56.2	3.2	56.2	3.2	
13AD		Higher Rate	132.5	3.0	397	1500	313	135.0	6.3	45.0	12.9	90.0	2.3	90.0	2.3	
BD			132.5	4.0	520	1500	313	112.5	5.2	45.0	9.3	67.5	2.2	67.5	2.2	
14AD			132.5	3.0	397	1000	313	127.5	4.9	60.0	7.3	67.5	3.2	67.5	3.2	
BD			132.5	4.0	520	1000	313	127.5	6.2	60.0	9.7	67.5	3.2	67.5	3.2	

TABLE 2
Analytical Results
Pilot Plant Tests

TEST No. PT.	Date 1986	PURPOSE	wt %	HEAD DATA			Calc. Head %Ash	wt. %	CONC. DATA			wt. %	%Dist. S	TAILING DATA			%Dist. Ash S					
				%Ash	%S	%H2O			Analyses	%Ash	%S			%H2O	Analyses	%Ash		%S				
5 A B 6 A B 7 A B 8 A B	Sept.	Preliminary	100.0	18.5	4.17	1.03	18.5	4.42	61.6	9.2	4.02	1.08	30.6	56.0	38.4	34.2	42.5	28.1	65.8			
			100.0	18.5	4.17	1.03	18.3	3.02	74.6	9.0	3.78	1.24	37.8	71.9	25.4	43.5	34.4	30.3	57.0			
			100.0	17.1	4.13	1.00	17.5	3.74	72.0	11.4	3.52	1.09	44.3	67.7	28.0	36.9	37.9	27.6	59.6			
			100.0	18.8	5.26	1.23	19.8	4.37	72.5	11.7	4.22	1.12	45.0	70.0	27.5	37.7	36.9	25.6	53.3			
9 A B 10A B 11A B 12A B	Sept.	Factorial	100.0	18.0	3.97	1.06	17.0	3.97	68.9	9.7	3.33	1.16	30.8	47.8	30.8	43.7	42.6	33.8	4.90	0.98	72.9	52.6
			100.0	18.0	3.97	1.06	17.0	3.97	68.9	9.7	3.33	1.16	30.8	47.8	30.8	43.7	42.6	33.8	4.90	0.98	72.9	52.6
			100.0	18.4	3.82	1.06	18.4	4.10	60.2	9.9	3.33	1.16	30.8	47.8	30.8	43.7	42.6	33.8	4.90	0.98	72.9	52.6
			100.0	18.4	3.82	1.06	18.4	4.10	60.2	9.9	3.33	1.16	30.8	47.8	30.8	43.7	42.6	33.8	4.90	0.98	72.9	52.6
9 AD FD 10AD FD 11AD FD 12AD FD	Nov.	Factorial Duplicates	100.0	17.6	3.53	0.85	17.8	4.23	66.8	7.95	3.51	0.66	29.8	55.4	33.2	37.7	32.4	39.0	5.54	0.63	68.6	42.7
			100.0	17.6	3.53	0.85	18.4	4.21	67.6	8.55	3.57	0.74	31.4	57.3	32.4	39.0	5.54	0.63	68.6	42.7		
			100.0	17.4	3.56	1.30	17.7	4.05	67.4	8.6	3.84	1.06	32.8	63.8	32.6	36.4	4.51	0.96	67.2	36.2		
			100.0	17.4	3.56	1.30	18.0	3.82	67.0	9.86	3.44	0.97	36.7	60.2	33.0	34.6	4.61	0.96	63.3	39.8		
3A B 4A B 3AD FD 4AD FD	Dec.	Higher Rate Duplicates	100.0	17.6	3.95	1.16	17.4	4.87	74.8	8.53	4.32	0.95	36.7	66.3	25.2	43.7	6.52	0.87	63.3	33.7		
			100.0	17.6	3.95	1.16	17.7	4.10	77.4	9.53	3.94	1.04	41.6	72.8	22.6	45.8	5.04	0.89	58.4	27.2		
			100.0	18.7	4.54	1.07	18.6	4.07	60.3	9.56	3.70	0.94	35.6	63.0	30.7	39.1	4.91	0.93	64.4	37.0		
			100.0	18.7	4.54	1.07	17.3	4.22	74.1	10.4	3.93	0.93	44.4	69.0	25.9	37.2	5.06	1.01	55.6	31.0		
3AD FD 4AD FD	Dec.	Higher Rate Duplicates	100.0	19.4	4.41		19.4	4.33	76.4	9.69	3.80		38.1	67.0	23.6	51.0	6.06				61.9	33.0
			100.0	18.7	4.41		18.7	4.38	68.4	9.56	3.92		34.9	62.2	31.6	38.5	5.24				65.1	37.8
			100.0	19.5	3.66		19.5	4.41	75.8	10.90	3.94		42.2	67.8	24.2	46.6	5.86				57.8	32.2
			100.0	19.1	3.66		19.1	4.43	76.1	11.54	3.98		46.0	68.2	23.9	43.2	5.90				54.0	31.8
3AD FD 4AD FD	Dec.	Higher Rate Duplicates	100.0	19.3	3.99		19.3	4.28	77.2	10.31	3.81		41.2	68.8	22.8	49.9	5.86				58.8	31.2
			100.0	20.5	3.99		20.5	3.49	75.7	11.77	2.95		43.4	63.9	24.3	47.8	5.20				53.5	36.1
			100.0	19.0	3.95		19.0	4.61	71.3	10.35	4.10		38.9	63.4	28.7	40.9	5.88				61.1	36.6
			100.0	18.2	3.95		18.2	4.31	72.8	10.38	3.59		41.6	60.7	27.2	39.0	6.23				58.4	39.3

FIGURE 5
PILOT PLANT RESULTS - ALL DATA TESTS 9-14

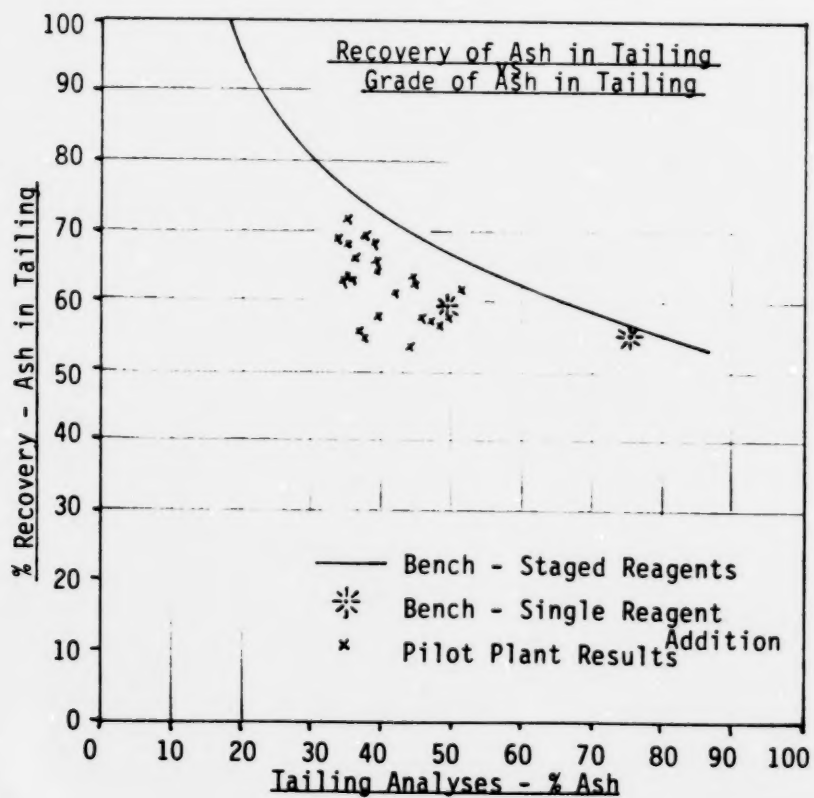
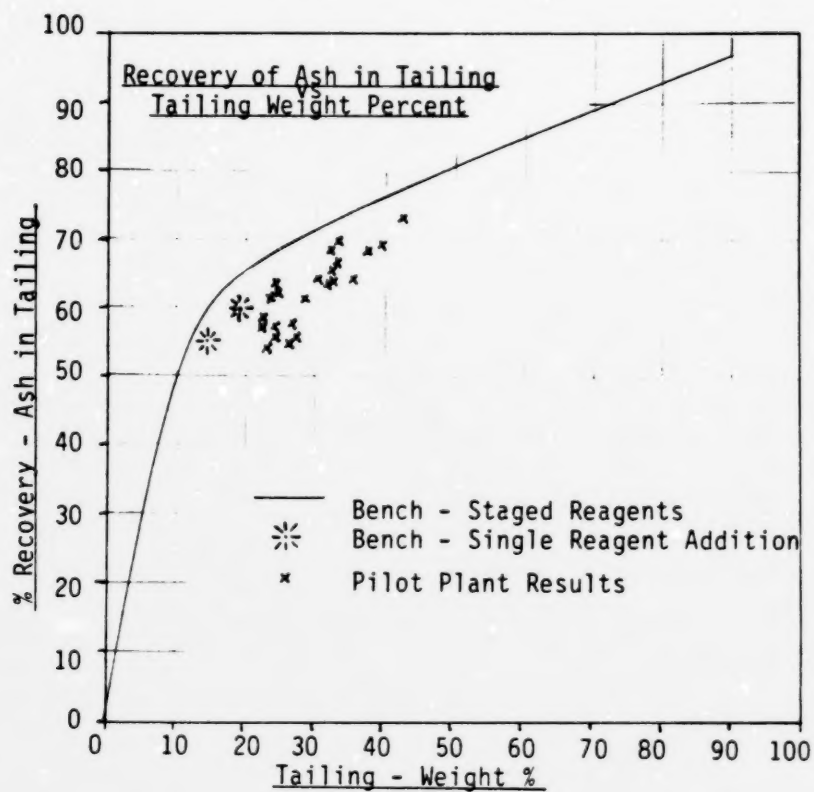


FIGURE 6
PILOT PLANT RESULTS-ALL DATA TESTS 9-14

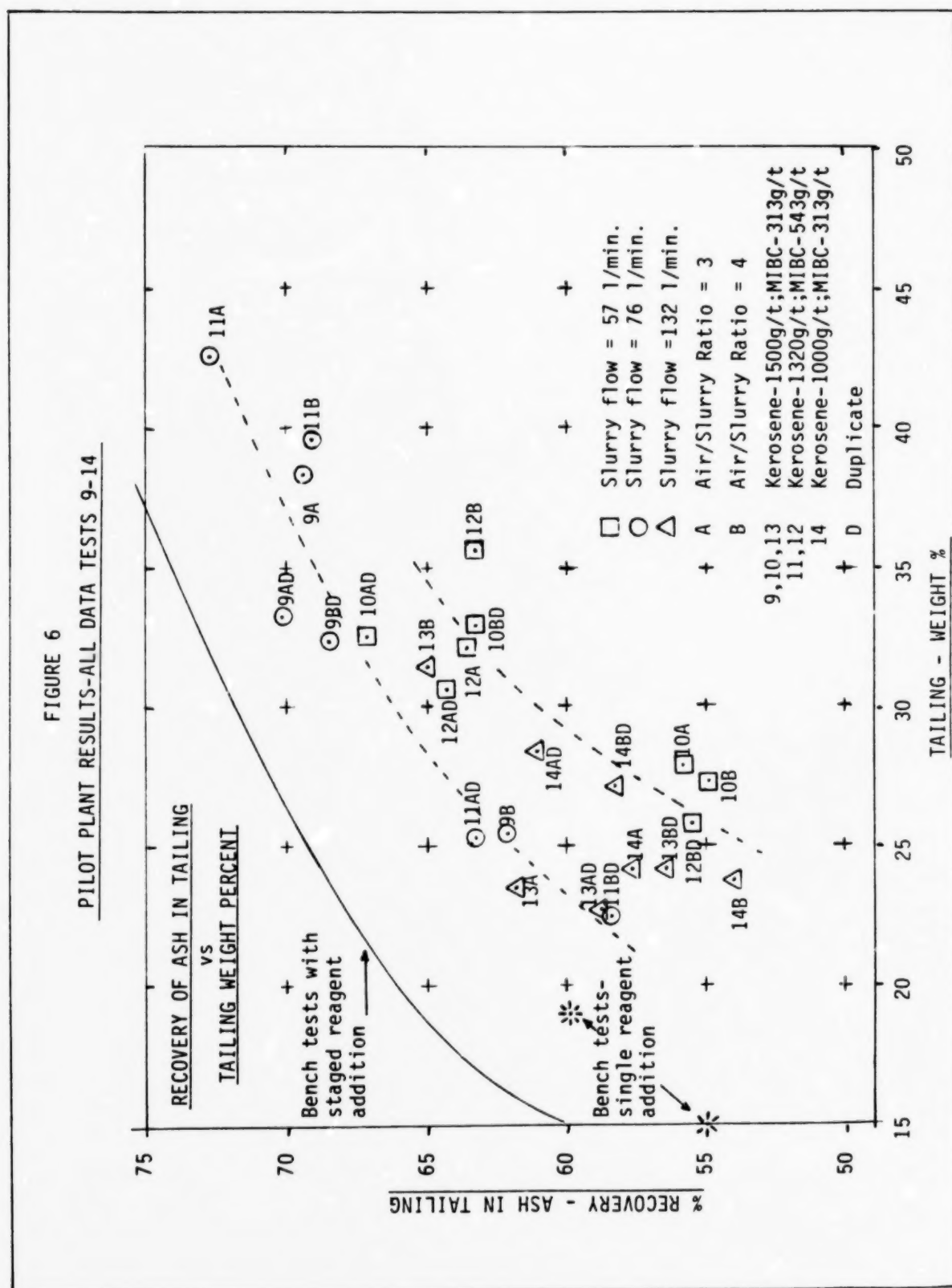
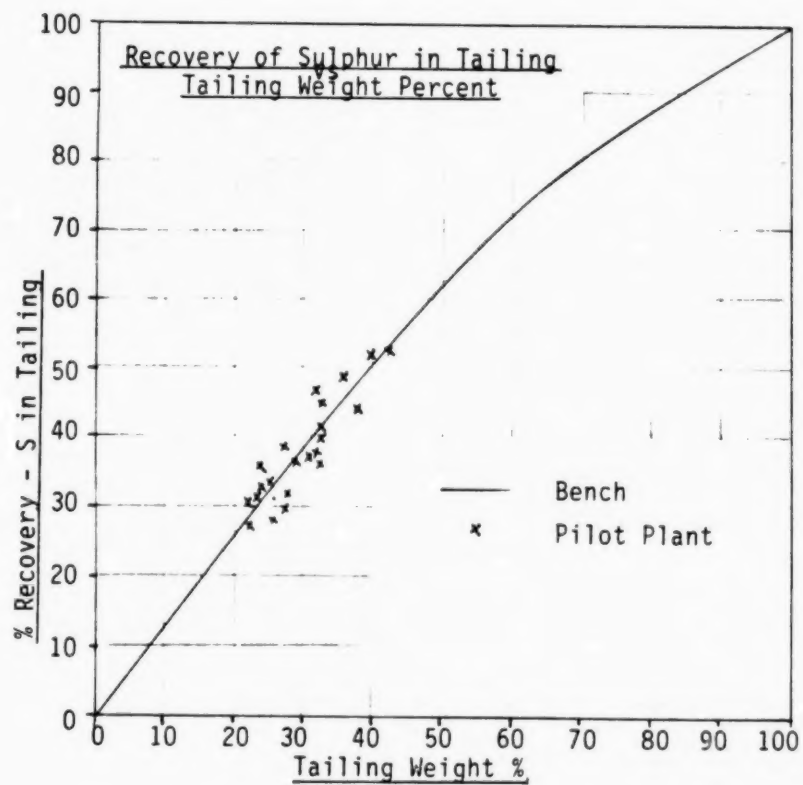


FIGURE 7
PILOT PLANT RESULTS - ALL DATA TESTS 9-14



Experimental Results (cont'd)

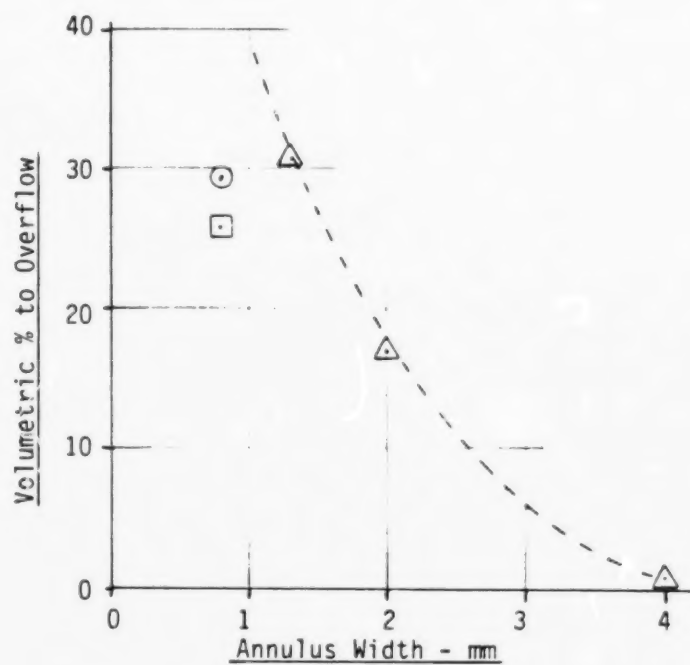
increasing the air to slurry ratio from 3 to 4 had a detrimental effect on recovery . Compare Tests 13A and 13B.

Kerosene collector reduction from 1500 g/tonne to 1320 g/tonne had little effect in Tests 9 to 12. However, in Test 14, reduction to 1000 g/tonne had a significant detrimental effect, indicating that the range of 1300 to 1500 g/tonne was roughly correct.

Discussion of Results

In Figure 6, the solid curve for bench work results represents a general response curve which is related to the grind or liberation, the type of reagent and the machine. With those things constant, reagent dosage, flotation time and air rate are the main variables which determine the position on that curve for a given test. It was assumed that a similar curve would be generated for the Air Sparged Hydrocyclone and that changing the feed rate (time) reagent dosage and air rate would likewise determine points on that curve. The relative positions of the curves for conventional and cyclone flotation would rate the machines. Unexpectedly, the relationship between feed rate and annulus opening is a variable which affects the position of the cyclone curve. Note in Figure 6 that clearly there is a curve for 57 l/min. and one for 76 l/min. which is closer to the the laboratory work curve. For these two flow rates the annulus opening was a constant - slightly less than 1 mm. This improvement was misinterpreted as being solely related to the centrifugal forces generated in the cyclone.

FIGURE 8
EFFECT OF ANNULUS OPENING ON THE
FLOTATION SPLIT



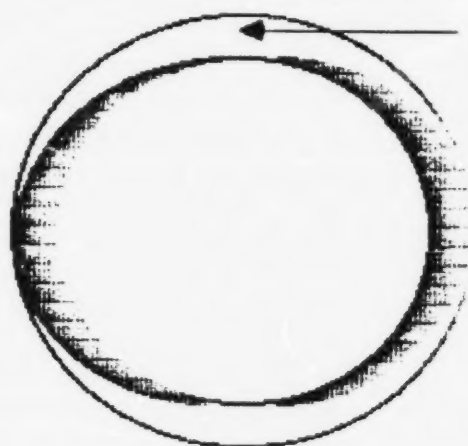
- Tests 9A, 9AD at 57 l/min.
- Tests 10A, 10AD at 76 l/min.
- △ Tests 13A, 13AD at 132 l/min.

Discussion of Results (cont'd)

At 132 l/min. however, no additional improvement was realized. It now seems probable that our failure to obtain better results at 132 l/min. was caused by our failure to recognize the importance of the annulus opening. As preparations were being made to test the higher feed rate we speculated that a larger annulus opening might be required to physically transport the tailing. As shown in Figure 8, this was not true. Double the feed rate did not require double the annulus opening and on the basis of Figure 8 the annulus size was deemed best to remain at 1 mm.

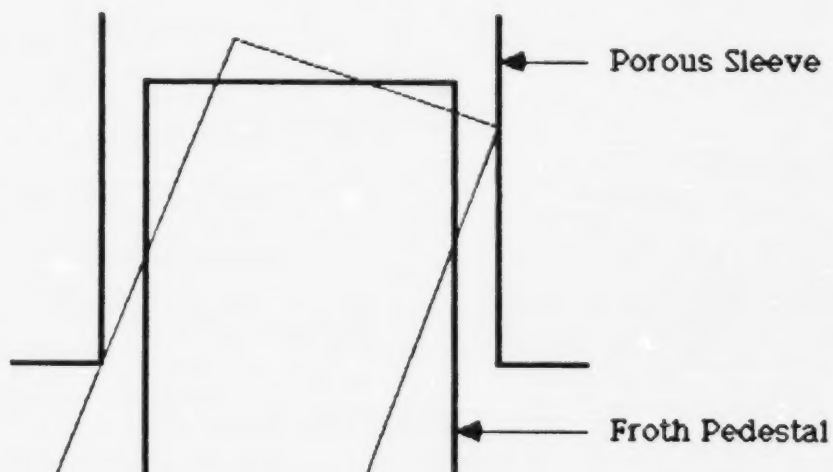
All should have been well - except that in performing the tests for Figure 8 the original annulus sleeve was damaged and had to be replaced. The new one was not quite identical, being approximately 1/2 mm smaller diameter. At the time, without all the results in hand, such a small difference was judged to be inconsequential.

Given the critical effect of annulus opening, the design of the froth pedestal support should provide more precision than did this one. Figure 9 shows the possible effect of sloppy mounting and no doubt accounts for some of the random inconsistency in the results of this work.



Annulus Between
Porous Sleeve and
Froth Pedestal. Shaded
Area Indicates Annulus
Reduction Caused by
Skewed Pedestal Mount

PLAN VIEW



SIDE VIEW

FIGURE 9

SKETCH SHOWING IMPORTANCE OF
PRECISION PEDESTAL MOUNTING

Water Analyses

Water analyses for Fredericton tap water and selected tailing samples are presented below. In addition, comprehensive water analyses provided through the courtesy of CANMET are compiled in Appendix II. Nothing immediately obvious was revealed by these analyses which are included for interest's sake.

SAMPLE	Ca	Mg	Na	K	Cl	SO ₄	NO ₃ /NO ₂ as N	HCO ₃	CO ₃	pH
Fredericton Tap Water	24.9	2.8	9.5	1.3	17.2	16.0	0.23	104.6	1.0	8.1
Test 9BD Tailing	31.4	4.4	12.9	2.4	23.6	92.0	0.17	14.2	1.0	5.9
Test 10BD Tailing	43.9	6.2	19.0	12.9	32.6	117.	0.33	11.2	1.0	4.6
Test 11BD Tailing	38.4	5.5	17.8	2.9	28.9	105.	0.28	20.9	1.0	7.1

Bibliography

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Fine Coal Flotation in a Centrifugal Field with an Air Sparged Hydrocyclone
Mining Engineering, November, 1982
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International Conference on Recent Advances in Mineral Science and Technology, March, 1984
- 3) Miller, J.D., Misra, M., Gopalakrishnan, S.
Fine Gold Flotation from Colorado River Sand with the Air Sparged Hydrocyclone
SME-AIME Fall Meeting, October, 1985
- 4) Miller, J.D., Upadrashta, K.R., Kinneberg, D.J., Gopalakrishnan, S.
Fluid Flow Phenomena in the Air Sparged Hydrocyclone
XV th International Mineral Processing Congress, June, 1985

APPENDIX I

SCREEN ANALYSIS REPORT

PROJECT: ASH - UP-S-603

DATE : July 24/86

SAMPLE : Minto Coal Flotation Grind

MESH SIZE	WEIGHT		CUM.%	CUM.% PASSING
	g	%		
28				
35				
48				
65		2.86	2.86	97.14
100		11.48	14.34	85.66
150		12.96	27.30	72.70
200		8.50	35.80	64.20
270		11.56	47.36	52.64
325		2.86	50.22	49.78
-325		49.78		
TOTAL		100.00		

SCREEN ANALYSIS REPORT

PROJECT: ASH - UP-S-603

DATE : July 24/86

SAMPLE : Prince Coal - Flotation Grind

MESH SIZE	WEIGHT g	%	CUM.%	CUM.% PASSING
28				
35				
48				
65		4.06	4.06	95.94
100		13.36	17.42	82.58
150		13.42	30.84	69.16
200		10.08	40.92	59.08
270		11.66	52.58	47.42
325		3.92	56.50	43.50
-325		43.50		
TOTAL		100.00		

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : July 23/86

SAMPLE : Minto Coal

TEST No: BF-2

PURPOSE: Exploratory

PREPARATION: 86 % -100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1

@2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS-g/tonne				COMMENTS
			Kern	MIBC			
Condition 1	2	6.4	540	108			
Flotation 1	½						Voluminous froth
Flotation 2	1						
			540	108			

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
1 Conc. 1	128.3	40.8	8.25	5.06		336.6	206.4	26.8	33.1	
2 Conc. 2	88.4	28.1	9.32	5.16		261.9	145.0	20.8	23.3	
3										
4										
5 Tailing	97.9	31.1	21.19	8.74		659.0	271.8	52.4	43.6	
HEAD	314.6	100.0				1257.5	623.2	100.0	100.0	

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : July 24/86

SAMPLE : Minto Coal

TEST No: BF-3

PURPOSE: To determine the effect of first flotation without reagents.

PREPARATION: 86 % - 100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1

@ 2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS - g/tonne			COMMENTS
			Kero	MIBC		
Flotation 1	1	6.4	--	--		
Condition 2	2		155	52		
Flotation 2	1					
Condition 3	2		258	52		
Flotation 3	2					Finished with a white, brittle froth
			413	104		

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES - %			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
1 Conc. 1	63.3	19.3	7.10	4.74		137.0	91.5	10.8	14.4	
2 Conc. 2	154.8	47.2	10.23	5.58		482.9	263.4	38.1	41.4	
3 Conc. 3	105.1	32.0	17.21	8.31		550.7	265.9	43.5	41.8	
4										
5 Tailing	4.9	1.5	64.49	9.95		96.7	14.9	7.6	2.4	
HEAD	328.1	100.0				1267.3	635.7	100.0	100.0	

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : July 24/86

SAMPLE : Minto Coal

TEST No: BF-4

PURPOSE: Repeat BF-3 at a lower pulp density

PREPARATION: 86 % -100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1

2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS - g/tonne				COMMENTS
			Kero	MIBC			
Flotation 1	1	6.6	--	--			
Condition 2	2		97	97			
Flotation 2	1						
Condition 3	2		194	97			
Flotation 3	2						Finished with clean brittle froth
			291	194			

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
1 Conc. 1	28.9	16.4	6.25	4.40		102.5	72.8	8.2	12.1	
2 Conc. 2	66.7	38.0	8.18	5.19		310.8	197.2	24.9	32.7	
3 Conc. 3	76.6	43.6	16.16	6.89		704.6	300.4	56.3	49.8	
4										
5 Tailing	3.5	2.0	66.15	16.25		132.3	32.5	10.6	5.4	
HEAD	175.7	100.0				1250.2	602.9	100.0	100.0	

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : July 24/86

SAMPLE : Minto Coal

TEST No: BF-5

PURPOSE: To determine the effect of pre-aeration

PREPARATION: 86 % - 100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1

@ 2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS - g/tonne			COMMENTS
			Kero	MIBC		
Pre-aeration *	5	6.6 7.3	--	--		
Flotation 1	1		--	--		
Condition 2	2		99	99		
Flotation 2	1					
Condition 3	2		--	99		
Flotation 3	2		--	99		Finished with clean brittle froth.
			99	297		

* Pre-aeration at 20% solids. pH after dilution to 3.5 % solids = 7.3

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
Conc. 1	47.5	27.8	6.35	4.31		176.5	119.8	13.9	19.4	
Conc. 2	61.1	35.8	9.38	5.54		335.8	198.3	26.4	32.1	
Conc. 3	48.5	28.4	15.05	6.59		427.4	187.2	33.5	30.3	
Tailing	13.8	8.0	41.82	14.13		334.6	113.0	26.2	18.2	
HEAD	170.9	100.0				1274.3	618.3	100.0	100.0	

COMMENT: Pre-aeration has some effect on the ionic balance and the flotation characteristic. Compared with BF-4, the rate of flotation was faster.

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : July 25/86

SAMPLE : Prince Coal

TEST No: BF-6

PURPOSE: Exploratory

PREPARATION: 83 % -100mesh

FLOTATION CONDITIONS: CELL - Denver D-1

2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS -g/tonne				COMMENTS
			Kero	MIBC			
Condition 1	2	5.7	152	51			Initial froth without reagents is empty.
Flotation 1	1						
Condition 2	2		152	51			
Flotation 2	1						
Condition 3	2		253	51			
Flotation 3	2		--	51			
			557	204			

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
Conc. 1	18.9	5.6	7.47	2.74		41.8	15.3	2.3	3.7	
Conc. 2	51.5	15.3	6.50	3.19		99.5	48.8	5.4	11.9	
Conc. 3	163.4	48.5	7.55	3.73		366.2	180.9	19.9	44.2	
Tailing	102.8	30.6	43.56	5.38		332.9	164.6	72.4	40.2	
HEAD	336.6	100.0				840.4	409.6	100.0	100.0	

COMMENT: Good looking froth. Seemed to be controllable with reagent addition.

FLOTATION TEST REPORT

PROJECT: ASH - UP-S 603

DATE : July 25/86

SAMPLE : Prince Coal

TEST No: BF-7

PURPOSE: To determine the effect of pre-aeration at 20% solids

PREPARATION: 83 % -100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1

@ 2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS - g/tonne				COMMENTS
			Kero	MIBC			
Pre-aeration *	5	5.7	--	--			
Condition 1	2		150	50			
Flotation 1	1						
Condition 2	2		200	50			
Flotation 2	1						
Condition 3	2		200	50			
Flotation 3	2		--	50			

* Pre-aeration at 20% solids. pH after dilution to 7% solids = 6.1

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
1 Conc. 1	26.3	7.8	7.08	2.92		55.2	22.8	3.1	5.6	
2 Conc. 2	88.6	26.1	6.97	3.04		181.9	79.3	10.3	19.4	
3 Conc. 3	177.5	52.4	9.83	3.70		515.1	193.9	29.0	47.5	
4										
5 Tailing	46.5	13.7	74.54	8.18		1021.2	112.2	57.6	27.5	
HEAD	338.9	100.0				1773.4	408.2	100.0	100.0	

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE: July 25/86

SAMPLE: Prince Coal

TEST No: CF-8

PURPOSE: To determine the effect of pre-aeration at 7% solids

PREPARATION: 83% -100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1

2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS -g/tonne				COMMENTS
			Kero	MEBC			
Pre-aeration *	10	5.1	--	--			
Condition 1	2		301	100			
Flotation 1	1						
Condition 2	2		201	50			
Flotation 2	1						
Condition 3	2		151	50			
Flotation 3	1	6.8		50			

* Pre-aeration : time/min. 1 2 3 4 5 7 10
pH 6.0 5.5 5.1 5.1

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION	
	g	%	Ash	S		Ash	S	Ash	S
1 Conc. 1	69.7	20.6	7.01	2.94		144.4	60.6	8.0	16.9
2 Conc. 2	102.5	30.3	7.56	3.04		229.1	92.1	12.7	25.7
3 Conc. 3	90.4	26.7	9.44	3.85		252.0	102.8	14.0	28.7
4									
5 Tailing	75.9	22.4	52.62	4.61		1170.7	103.3	65.3	28.7
HEAD	338.5	100.0				1804.2	358.8	100.0	100.0

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE: July 25/86

SAMPLE: Prince Coal

TEST No: BF-9

PURPOSE: To repeat BF-7, monitoring pH of aeration at 20% solids and adding greater percentage of reagents to first flotation.

PREPARATION: 83% - 100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1 @ 2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS-g/tonne				COMMENTS
			Kero	MIBC			
Pre-aeration *	10	5.8 6.2	--	--			
Condition 1	2		292	97			
Flotation 1	1						
Condition 2	2		195	49			
Flotation 2	1						
Condition 3	2		146	49			
Flotation 3	1						

* Pre-aeration : time/min. 0 1 3 5 7 10

pH 4.7 4.6 4.6 4.7 4.5) pH after dilution to
7% solids = 6.2

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES-%			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
1 Conc. 1	170.0	48.7	7.26	3.77		353.5	183.6	19.8	39.8	
2 Conc. 2	119.8	34.3	10.58	5.45		362.9	186.9	20.3	40.5	
3 Conc. 3	18.9	5.4	20.21	5.55		109.1	30.0	6.1	6.5	
4										
5 Tailing	40.5	11.6	82.81	5.26		960.6	61.0	53.8	13.2	
HEAD	349.2	100.0				1786.1	461.5	100.0	100.0	

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : July 28/86

SAMPLE : Prince Coal

TEST No: BF-10

PURPOSE: Without pre-aeration to determine the effect of adding all of the reagent to the first conditioning.

PREPARATION: 83 % -100 mesh

FLOTATION CONDITIONS: CELL - Denver D-1 @ 2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS - g/tonne				COMMENTS
			Kero	MIBC			
Condition 1	2	6.1	631	243			
Flotation 1	3						
		6.6					

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES - %			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
1 Conc. 1	280.2	80.1	8.43	4.01		675.2	321.2	41.0	74.6	
2										
3										
4										
5 Tailings	69.6	19.9	48.77	5.48		970.5	109.1	59.0	25.4	
HEAD	349.8	100.0				1645.7	430.3	100.0	100.0	

COMMENT: _____

FLOTATION TEST REPORT

PROJECT: ASH - UP-S-603

DATE : Sept. 25/86

SAMPLE : Prince Coal

TEST No: BF-11

PURPOSE: Continuity reference

PREPARATION: Sample taken from pilot plant feed to test PT 10

FLOTATION CONDITIONS: CELL - Denver D-1 @ 2100 RPM

OPERATION	TIME MIN.	pH	REAGENTS - g/tonne				COMMENTS
			Kero	MIBC			
Condition 1	2		10 dp	2dp			
Flotation 1	2		--	2dp			
Condition 2	2		3dp	2dp			
Flotation 2	1						Very low wt. recovery
							conc. added to conc. 1

FLOTATION RESULTS:

PRODUCT	WEIGHT		ANALYSES - %			UNITS		% DISTRIBUTION		
	g	%	Ash	S		Ash	S	Ash	S	
Conc. 1+2	260.7	86.1	9.8			843.8		44.3		
Tailing	42.2	13.9	76.2			1059.2		55.7		
HEAD	302.9	100.0				1903.0		100.0		

COMMENT: Calculated head @ 19 % ash agrees with sampled head of PT-10
@ 19 % ash. Results likewise confirm earlier results.

APPENDIX II



ENVIRO - TEST LABS

9936 - 67 AVENUE
EDMONTON, ALBERTA T6E 0P5
PHONE (403) 434-9509

In cooperation with MORWEST SOIL RESEARCH LTD.

DATE	31-OCT-86
P.O. NO	
W.O. NO	14265

ENERGY MINES AND
RESOURCES

IAN PARSONS

NOV 0 5 1986

NAQUADAT -----101-----102-----				NAQUADAT -----101-----102-----			
SITE		PT9 HEAD	PT9A CONC		PT9 HEAD	PT9A CONC	
DESC.							
SAMPLE ID							
PH	10301L	4.8	4.9	CADMIUM mg/L	48009	0.003	<.002
EC uS/cm	02041L	480	450	CHROMIUM mg/L	24009	<.002	<.002
CALCIUM mg/L	20103L	55	44	COBALT mg/L	27311P	0.16	0.14
MAGNESIUM mg/L	12102L	6.5	6.5	COPPER mg/L	29009	0.039	0.034
SODIUM mg/L	11102L	25	24	LEAD mg/L	82211P	<.05	<.05
POTASSIUM mg/L	19103L	4.3	3.8	MANGANESE mg/L	25609	2.08	1.75
IRON mg/L	26304L	3.06	1.62	MOLYBDENUM mg/L	42311P	<.01	<.01
SULPHATE mg/L	16306L	175	141	NICKEL mg/L	28311P	0.34	0.29
CHLORIDE mg/L	17203L	36.6	35.6	SILICON mg/L	14111P	4.25	4.01
CARBONATE mg/L	06301L	<1	<1	THORIUM mg/L		<.05	<.05
BICARBONATE mg/L	06201L	2	4	URANIUM mg/L	92111L	<.2	<.2
T ALKALINITY mg/L	10101L	1.6	3.3	VANADIUM mg/L	30009	<.002	<.002
T HARDNESS mg/L	10602L	163	135	ZINC mg/L	30311P	0.193	0.172
T DIS SOLIDS mg/L	00203L	306	257	REL DEN.		1.01	1.01
P ALKALINITY mg/L	10151L	<1	<1	REDOX POT.		463	351
FLUORIDE mg/L	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5
PHOSPHATE ORT mg/L	15256L	<0.005	<0.005				
RESIDUE FILT mg/L	10451L	325	315				
RESID NONFILT mg/L	10401L	6	4				
NITRATE mg/L	07301L	0.33	0.24				
NITRITE mg/L	07205P	<0.05	<0.05				
ALUMINIUM mg/L	13311P	0.27	0.27				
ARSENIC mg/L		<.2	<.2				
BARIUM mg/L	56009	0.025	0.027				

Solids* is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Collins



ENVIRO - TEST LABS

9936 - 67 AVENUE
EDMONTON, ALBERTA T6E 0P5
PHONE (403) 434-9509

In cooperation with NORMEST SOIL RESEARCH LTD.

DATE	31-OCT-86
P O NO	
W O NO	14269

ENERGY MINES AND
RESOURCES

IAM PARSONS

NAQUADAT -----103-----				-----104-----			
SITE		PT9B TAIL	PT9B CONC		NAQUADAT -----103-----	PT9B TAIL	PT9B CONC
DESC.		A?					
SAMPLE ID							
FM	10301L	4.8	5.1	CADMIUM $\mu\text{S/L}$	48009	<.002	0.002
EC $\mu\text{S/cm}$	02041L	480	480	CHROMIUM $\mu\text{S/L}$	24009	<.002	<.002
CALCIUM $\mu\text{S/L}$	20103L	51	51	COBALT $\mu\text{S/L}$	27311P	0.15	0.15
MAGNESIUM $\mu\text{S/L}$	12102L	5.5	6.5	COPPER $\mu\text{S/L}$	29009	0.028	0.032
SODIUM $\mu\text{S/L}$	11102L	25	24	LEAD $\mu\text{S/L}$	82211P	<.05	<.05
POTASSIUM $\mu\text{S/L}$	19103L	4.2	4.0	MANGANESE $\mu\text{S/L}$	25009	1.97	2.06
IRON $\mu\text{S/L}$	26304L	2.86	1.23	MOLYBDENUM $\mu\text{S/L}$	42311P	<.01	<.01
SULPHATE $\mu\text{S/L}$	16306L	149	144	NICKEL $\mu\text{S/L}$	28311P	0.33	0.33
CHLORIDE $\mu\text{S/L}$	17203L	33.8	40.1	SILICON $\mu\text{S/L}$	14111P	4.06	4.37
CARBONATE $\mu\text{S/L}$	06301L	<1	<1	THURIUM $\mu\text{S/L}$		<.05	<.05
BICARBONATE $\mu\text{S/L}$	06201L	2	8	URANIUM $\mu\text{S/L}$	92111L	<.2	<.2
T ALKALINITY $\mu\text{S/L}$	10101L	1.6	6.6	VANADIUM $\mu\text{S/L}$	30009	<.002	<.002
T HARDNESS $\mu\text{S/L}$	10602L	151	154	ZINC $\mu\text{S/L}$	30311P	0.177	0.212
T DIS SOLIDS $\mu\text{S/L}$	00203L	273	275	REL DEN.		1.01	1.00
P ALKALINITY $\mu\text{S/L}$	10151L	<1	<1	REDOX POT.		314	440
FLUORIDE $\mu\text{S/L}$	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5
PHOSPHATE ORT $\mu\text{S/L}$	15256L	<0.005	<0.005				
RESIDUE FILT $\mu\text{S/L}$	10451L	330	300				
RESID NONFILT $\mu\text{S/L}$	10401L	5	3				
NITRATE $\mu\text{S/L}$	07301L	0.28	0.15				
NITRITE $\mu\text{S/L}$	07205P	<0.05	<0.05				
ALUMINIUM $\mu\text{S/L}$	13311P	0.22	0.32				
ARSENIC $\mu\text{S/L}$		<.2	<.2				
BARIUM $\mu\text{S/L}$	56009	0.015	0.030				

Solids is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Collins



ENVIRO - TEST LABS

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ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	MAQUADAT -----105-----		-----106-----		MAQUADAT -----105-----		-----106-----	
	PT9B TAIL		PT10 HEAD		PT9B TAIL		PT10 HEAD	
PH	10301L	4.9	4.7	CADMIUM $\mu\text{g/L}$	48009	<.002	<.002	
EC $\mu\text{S/cm}$	02041L	480	490	CHROMIUM $\mu\text{g/L}$	24009	<.002	<.002	
CALCIUM $\mu\text{g/L}$	20103L	49	54	COBALT $\mu\text{g/L}$	27311P	0.16	0.17	
MAGNESIUM $\mu\text{g/L}$	12102L	6.2	6.8	COPPER $\mu\text{g/L}$	29009	0.026	0.035	
SODIUM $\mu\text{g/L}$	11102L	24	24	LEAD $\mu\text{g/L}$	02211P	<.05	<.05	
POTASSIUM $\mu\text{g/L}$	19103L	4.3	4.1	MANGANESE $\mu\text{g/L}$	25009	2.04	2.30	
IRON $\mu\text{g/L}$	26304L	2.53	4.90	MOLYBDENUM $\mu\text{g/L}$	42311P	<.01	<.01	
SULPHATE $\mu\text{g/L}$	16306L	156	148	NICKEL $\mu\text{g/L}$	28311P	0.34	0.35	
CHLORIDE $\mu\text{g/L}$	17203L	34.0	37.1	SILICON $\mu\text{g/L}$	14111P	4.03	4.50	
CARBONATE $\mu\text{g/L}$	04301L	<1	<1	THORIUM $\mu\text{g/L}$		<.05	<.05	
BICARBONATE $\mu\text{g/L}$	06201L	8	4	URANIUM $\mu\text{g/L}$	92111L	<.2	<.2	
T ALKALINITY $\mu\text{g/L}$	10101L	6.6	3.3	VANADIUM $\mu\text{g/L}$	30009	0.034	<.002	
T HARDNESS $\mu\text{g/L}$	10602L	148	163	ZINC $\mu\text{g/L}$	30311P	0.193	0.161	
T TDS SOLIDS $\mu\text{g/L}$	00203L	280	281	REL DEN.		1.01	1.02	
P ALKALINITY $\mu\text{g/L}$	10151L	<1	<1	REDOX POT.		324	300	
FLUORIDE $\mu\text{g/L}$	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5	
PHOSPHATE ORT $\mu\text{g/L}$	15256L	<0.005	<0.005					
RESIDUE FILT $\mu\text{g/L}$	10451L	330	345					
RESID NOMFILT $\mu\text{g/L}$	10401L	6	6					
NITRATE $\mu\text{g/L}$	07301L	0.28	0.15					
NITRITE $\mu\text{g/L}$	07205P	<0.05	<0.05					
ALUMINIUM $\mu\text{g/L}$	13311P	0.23	0.35					
ARSENIC $\mu\text{g/L}$		<.2	<.2					
BARIUM $\mu\text{g/L}$	56009	0.018	0.017					

Solids is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Callin



ENVIRO - TEST LABS

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ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	MAQUADAT -----107-----		-----108-----		MAQUADAT -----107-----		-----108-----	
	PT10A CONC		PT10A TAIL		PT10A CONC		PT10A TAIL	
PH	10301L	4.8	5.1	CADMIUM $\mu\text{g/L}$	48009	<.002	<.002	
EC $\mu\text{S/cm}$	02041L	460	470	CHROMIUM $\mu\text{g/L}$	24009	<.002	<.002	
CALCIUM $\mu\text{g/L}$	20103L	52	54	COBALT $\mu\text{g/L}$	27311P	0.15	0.16	
MAGNESIUM $\mu\text{g/L}$	12102L	6.5	7.0	COPPER $\mu\text{g/L}$	29009	0.030	0.025	
SODIUM $\mu\text{g/L}$	11102L	24	24	LEAD $\mu\text{g/L}$	82211P	<.05	<.05	
POTASSIUM $\mu\text{g/L}$	19103L	3.8	4.0	MANGANESE $\mu\text{g/L}$	25009	1.92	2.12	
IRON $\mu\text{g/L}$	26304L	2.37	2.53	MOLYBDENUM $\mu\text{g/L}$	42311P	<.01	<.01	
SULPHATE $\mu\text{g/L}$	16306L	149	149	NICKEL $\mu\text{g/L}$	28311P	0.32	0.34	
CHLORIDE $\mu\text{g/L}$	17203L	34.8	31.7	SILICON $\mu\text{g/L}$	14111P	4.24	4.29	
CARBONATE $\mu\text{g/L}$	06301L	<1	<1	THORIUM $\mu\text{g/L}$		<.05	<.05	
BICARBONATE $\mu\text{g/L}$	06201L	4	20	URANIUM $\mu\text{g/L}$	92111L	<.2	<.2	
T ALKALINITY $\mu\text{g/L}$	10101L	3.3	16.5	VANADIUM $\mu\text{g/L}$	30009	<.002	<.002	
T HARDNESS $\mu\text{g/L}$	10602L	157	162	ZINC $\mu\text{g/L}$	30311P	0.145	0.153	
T DIS SOLIDS $\mu\text{g/L}$	00203L	275	281	REL DEN.		1.01	1.00	
P ALKALINITY $\mu\text{g/L}$	10151L	<1	<1	REDOX POT.		413	316	
FLUORIDE $\mu\text{g/L}$	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5	
PHOSPHATE ORT $\mu\text{g/L}$	15256L	<0.005	<0.005					
RESIDUE FILT $\mu\text{g/L}$	10451L	330	330					
RESID NONFILT $\mu\text{g/L}$	10401L	6	6					
NITRATE $\mu\text{g/L}$	07301L	0.24	0.27					
NITRITE $\mu\text{g/L}$	07205P	<0.05	<0.05					
ALUMINIUM $\mu\text{g/L}$	13311P	0.26	0.22					
ARSENIC $\mu\text{g/L}$		<.2	<.2					
BARIUM $\mu\text{g/L}$	56009	0.024	0.016					

Solids* is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Collins



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ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	MAQUADAT -----109-----		-----110-----		MAQUADAT -----109-----		-----110-----	
	PT10B CONC		PT10B TAIL		PT10B CONC		PT10B TAIL	
PH	10301L	4.9	4.8	CADMIUM $\mu\text{g/L}$	48009	<.002	0.003	
EC $\mu\text{S/cm}$	02041L	460	470	CHROMIUM $\mu\text{g/L}$	24009	<.002	<.002	
CALCIUM $\mu\text{g/L}$	20103L	52	52	COBALT $\mu\text{g/L}$	27311P	0.16	0.16	
MAGNESIUM $\mu\text{g/L}$	12102L	6.2	6.5	COPPER $\mu\text{g/L}$	29009	0.035	0.039	
SODIUM $\mu\text{g/L}$	11102L	24	24	LEAD $\mu\text{g/L}$	02211P	<.05	<.05	
POTASSIUM $\mu\text{g/L}$	19103L	3.8	3.9	MANGANESE $\mu\text{g/L}$	25009	2.10	2.10	
IRON $\mu\text{g/L}$	26304L	2.18	2.55	MOLYBDENUM $\mu\text{g/L}$	42311P	<.01	<.01	
SULPHATE $\mu\text{g/L}$	16306L	149	152	NICKEL $\mu\text{g/L}$	28311P	0.33	0.33	
CHLORIDE $\mu\text{g/L}$	17203L	36.0	31.7	SILICON $\mu\text{g/L}$	14111P	4.42	4.28	
CARBONATE $\mu\text{g/L}$	06301L	<1	<1	THORIUM $\mu\text{g/L}$		<.05	<.05	
BICARBONATE $\mu\text{g/L}$	06201L	12	12	URANIUM $\mu\text{g/L}$	92111L	<.2	<.2	
T ALKALINITY $\mu\text{g/L}$	10101L	9.9	9.9	VANADIUM $\mu\text{g/L}$	30009	<.002	<.002	
T HARDNESS $\mu\text{g/L}$	10602L	155	157	ZINC $\mu\text{g/L}$	30311P	0.158	0.137	
T DIS SOLIDS $\mu\text{g/L}$	00203L	279	279	REL DEN.		1.01	1.01	
P ALKALINITY $\mu\text{g/L}$	10151L	<1	<1	REDOX POT.		314	411	
FLUORIDE $\mu\text{g/L}$	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5	
PHOSPHATE ORT $\mu\text{g/L}$	15256L	<0.005	<0.005					
RESIDUE FILT $\mu\text{g/L}$	10451L	300	310					
RESID NONFILT $\mu\text{g/L}$	10401L	3	2					
NITRATE $\mu\text{g/L}$	07301L	0.18	0.25					
NITRITE $\mu\text{g/L}$	07205P	<0.05	<0.05					
ALUMINIUM $\mu\text{g/L}$	13311P	0.52	0.24					
ARSENIC $\mu\text{g/L}$		<.2	<.2					
BARIUM $\mu\text{g/L}$	56009	0.022	0.017					

Solids is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

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ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	NAQUADAT -----111-----		-----112-----		NAQUADAT -----111-----		-----112-----	
	PT11 HEAD		PT11A CONC		PT11 HEAD		PT11A CONC	
PH	10301L	4.7	5.2	CADMIUM mg/L	48009	0.002	<0.02	
EC uS/cm	07041L	480	460	CHROMIUM mg/L	24009	<0.02	<0.02	
CALCIUM mg/L	20103L	52	52	COBALT mg/L	27311P	0.16	0.13	
MAGNESIUM mg/L	12102L	6.2	5.8	COPPER mg/L	29009	0.033	0.033	
SODIUM mg/L	11102L	28	25	LEAD mg/L	82211P	<0.05	<0.05	
POTASSIUM mg/L	19103L	4.0	3.7	MANGANESE mg/L	25009	1.89	1.73	
IRON mg/L	26304L	6.30	1.37	MOLYBDENUM mg/L	42311P	<0.01	<0.01	
SULPHATE mg/L	14306L	169	139	NICKEL mg/L	28311P	0.34	0.27	
CHLORIDE mg/L	17203L	34.8	37.9	SILICON mg/L	14111P	4.40	4.00	
CARBONATE mg/L	06301L	<1	<1	THORIUM mg/L		<0.05	<0.05	
BICARBONATE mg/L	06201L	8	20	URANIUM mg/L	92111L	<0.2	<0.2	
T ALKALINITY mg/L	10101L	6.6	16.5	VANADIUM mg/L	30009	<0.02	<0.02	
T HARDNESS mg/L	10602L	156	154	ZINC mg/L	30311P	0.124	0.101	
T DIS SOLIDS mg/L	00203L	304	275	REL DEN.		1.00	1.00	
P ALKALINITY mg/L	10151L	<1	<1	REDOX POT.		308	300	
FLUORIDE mg/L	07105L	<0.1	<0.1	BROMIDE		<0.5	<0.5	
PHOSPHATE ORT mg/L	15256L	<0.005	<0.005					
RESIDUE FILT mg/L	10451L	355	315					
RESID NONFILT mg/L	10401L	11	3					
NITRATE mg/L	07301L	0.31	0.28					
NITRITE mg/L	07205P	<0.05	<0.05					
ALUMINIUM mg/L	13311P	0.22	0.26					
ARSENIC mg/L		<0.2	<0.2					
BARIUM mg/L	56009	0.012	0.024					

Solids is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Callin



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ENERGY MINES AND
RESOURCES

IAM PARSONS

		MAQUADAT -----113-----114-----		MAQUADAT -----113-----114-----	
SITE		PT11A TAIL	PT11B CONC	PT11A TAIL	PT11B CONC
DESC.					
SAMPLE ID					
PH	10301L	4.8	5.0	CADMIUM $\mu\text{g/L}$	48009 <.002 <.002
EC $\mu\text{S/cm}$	02041L	500	470	CHROMIUM $\mu\text{g/L}$	24009 <.002 <.002
CALCIUM $\mu\text{g/L}$	20103L	54	49	CORAL T $\mu\text{g/L}$	27311P 0.17 0.14
MAGNESIUM $\mu\text{g/L}$	12102L	6.5	6.2	COPPER $\mu\text{g/L}$	29009 0.025 0.035
SODIUM $\mu\text{g/L}$	11102L	27	24	LEAD $\mu\text{g/L}$	82211P <.05 <.05
POTASSIUM $\mu\text{g/L}$	19103L	4.3	3.9	MANGANESE $\mu\text{g/L}$	25009 2.12 1.91
IRON $\mu\text{g/L}$	26304L	3.19	1.38	MOLYBDENUM $\mu\text{g/L}$	42311P <.01 <.01
SULPHATE $\mu\text{g/L}$	16306L	154	142	NICKEL $\mu\text{g/L}$	28311P 0.36 0.31
CHLORIDE $\mu\text{g/L}$	17203L	35.8	37.1	SILICON $\mu\text{g/L}$	14111P 4.38 4.25
CARBONATE $\mu\text{g/L}$	04301L	<1	<1	THORIUM $\mu\text{g/L}$	<.05 <.05
BICARBONATE $\mu\text{g/L}$	06201L	8	20	URANIUM $\mu\text{g/L}$	92111L <.2 <.2
T ALKALINITY $\mu\text{g/L}$	10101L	6.6	16.5	VANADIUM $\mu\text{g/L}$	30009 <.002 <.002
T HARDNESS $\mu\text{g/L}$	10602L	162	148	ZINC $\mu\text{g/L}$	30311P 0.148 0.131
T DIS SOLIDS $\mu\text{g/L}$	00203L	288	274	REL DEN.	1.01 1.01
P ALKALINITY $\mu\text{g/L}$	10151L	<1	<1	REDOX POT.	398 330
FLUORIDE $\mu\text{g/L}$	09105L	<0.1	<0.1	BROMIDE	<0.5 <0.5
PHOSPHATE ORT $\mu\text{g/L}$	15256L	<0.005	<0.005		
RESIDUE FILT $\mu\text{g/L}$	10451L	345	325		
RESID NONFILT $\mu\text{g/L}$	10401L	5	2		
NITRATE $\mu\text{g/L}$	07301L	0.28	0.26		
NITRITE $\mu\text{g/L}$	07205P	<0.05	<0.05		
ALUMINIUM $\mu\text{g/L}$	13311P	0.24	0.26		
ARSENIC $\mu\text{g/L}$		<.2	<.2		
BARIUM $\mu\text{g/L}$	56009	0.016	0.022		

Solids* is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Calli



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ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	MAQUADAT -----115-----		-----116-----		MAQUADAT -----115-----		-----116-----	
	PT11B TAIL		PT12 HEAD		PT11B TAIL		PT12 HEAD	
PH	10301L	4.8	5.1		CADMIUM mg/L	48009	<.002	<.002
EC uS/cm	02041L	490	470		CHROMIUM mg/L	24009	<.002	<.002
CALCIUM mg/L	20103L	50	50		COBALT mg/L	27311P	0.17	0.16
MAGNESIUM mg/L	12102L	6.8	5.5		COPPER mg/L	29009	0.031	0.033
SODIUM mg/L	11102L	27	25		LEAD mg/L	82211P	<.05	<.05
POTASSIUM mg/L	19103L	4.2	4.1		MANGANESE mg/L	25009	2.08	2.07
IRON mg/L	26304L	3.22	2.22		MOLYBDENUM mg/L	42311P	<.01	<.01
SULPHATE mg/L	16306L	151	138		NICKEL mg/L	28311P	0.35	0.33
CHLORIDE mg/L	17203L	35.4	37.8		SILICON mg/L	14111P	4.24	4.40
CARBONATE mg/L	06301L	<1	<1		THORIUM mg/L		<.05	<.05
BICARBONATE mg/L	06201L	8	<1		URANIUM mg/L	92111L	<.2	<.2
T ALKALINITY mg/L	10101L	6.6	<1.0		VANADIUM mg/L	30009	<.002	<.002
T HARDNESS mg/L	10602L	153	148		ZINC mg/L	30311P	0.142	0.138
T DIS SOLIDS mg/L	00203L	281	263		REL DEN.		1.00	1.00
P ALKALINITY mg/L	10151L	<1	<1		REDOX POT.		309	391
FLUORIDE mg/L	09105L	<0.1	<0.1		BROMIDE		<0.5	<0.5
PHOSPHATE ORT mg/L	15256L	<0.005	<0.005					
RESIDUE FILT mg/L	10451L	340	335					
RESID NONFILT mg/L	10401L	4	4					
NITRATE mg/L	07301L	0.27	0.16					
NITRITE mg/L	07205P	<0.05	<0.05					
ALUMINIUM mg/L	13311P	0.25	0.30					
ARSENIC mg/L		<.2	<.2					
BARIUM mg/L	56009	0.016	0.018					

Solids* is a calculated sum of dissolved constituents.

Nitrate Nitrite is expressed as Nitrogen.

Alkalinity is Carbonate & Bicarbonate expressed as Calcium Carbonate.

Conductivity (E.C.) is in microsiemens/cm and is a measure of Solids.

Hardness is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Collins



ENVIRO - TEST LABS

9936 - 67 AVENUE
EDMONTON, ALBERTA T6E 0P5
PHONE (403) 434-9509

In cooperation with MORVEST SOIL RESEARCH LTD.

DATE	31-OCT-86
P O NO	
W O NO	14269

ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	MAQUADAT -----117-----		-----118-----		MAQUADAT -----117-----		-----118-----	
	PT12A CONC		PT12A TAIL		PT12A CONC		PT12A TAIL	
PH	10301L	5.2	5.2	CADMIUM $\mu\text{g/L}$	48009	<.002	<.002	
EC $\mu\text{S/cm}$	02041L	440	470	CHROMIUM $\mu\text{g/L}$	24009	<.002	<.002	
CALCIUM $\mu\text{g/L}$	20103L	47	49	COBALT $\mu\text{g/L}$	27311P	0.14	0.16	
MAGNESIUM $\mu\text{g/L}$	12102L	7.0	7.3	COPPER $\mu\text{g/L}$	29009	0.025	0.023	
SODIUM $\mu\text{g/L}$	11102L	23	24	LEAD $\mu\text{g/L}$	82211P	<.05	<.05	
POTASSIUM $\mu\text{g/L}$	19103L	3.8	4.2	MANGANESE $\mu\text{g/L}$	25009	1.84	2.07	
IRON $\mu\text{g/L}$	26304L	0.69	1.09	MOLYBDENUM $\mu\text{g/L}$	42311P	0.01	<.01	
SULPHATE $\mu\text{g/L}$	16306L	131	145	NICKEL $\mu\text{g/L}$	28311P	0.30	0.33	
CHLORIDE $\mu\text{g/L}$	17203L	35.8	34.6	SILICON $\mu\text{g/L}$	14111P	3.98	4.12	
CARBONATE $\mu\text{g/L}$	06301L	<1	<1	THORIUM $\mu\text{g/L}$		<.05	<.05	
BICARBONATE $\mu\text{g/L}$	06201L	<1	<1	URANIUM $\mu\text{g/L}$	92111L	<.2	<.2	
T ALKALINITY $\mu\text{g/L}$	10101L	<1.0	<1.0	VANADIUM $\mu\text{g/L}$	30009	<.002	<.002	
T HARDNESS $\mu\text{g/L}$	10602L	145	153	ZINC $\mu\text{g/L}$	30311P	0.126	0.135	
T DIS SOLIDS $\mu\text{g/L}$	00203L	249	266	REL DEN.		1.01	1.01	
P ALKALINITY $\mu\text{g/L}$	10151L	<1	<1	REDOX POT.		327	283	
FLUORIDE $\mu\text{g/L}$	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5	
PHOSPHATE ORT $\mu\text{g/L}$	15256L	<0.005	<0.005					
RESIDUE FILT $\mu\text{g/L}$	10451L	315	320					
RESID NONFILT $\mu\text{g/L}$	10401L	1	3					
NITRATE $\mu\text{g/L}$	07301L	0.20	0.28					
NITRITE $\mu\text{g/L}$	07205P	<0.05	<0.05					
ALUMINIUM $\mu\text{g/L}$	13311P	0.23	0.22					
ARSENIC $\mu\text{g/L}$		<.2	<.2					
BARIUM $\mu\text{g/L}$	56009	0.022	0.015					

"Solids" is a calculated sum of dissolved constituents.

"Nitrate Nitrite" is expressed as Nitrogen.

"Alkalinity" is Carbonate & Bicarbonate expressed as Calcium Carbonate.

"Conductivity" (E.C.) is in microsiemens/cm and is a measure of Solids.

"Hardness" is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

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In cooperation with NORWEST SOIL RESEARCH LTD.

DATE	31-OCT-86
P O NO	
W O NO	14269

ENERGY MINES AND
RESOURCES

IAN PARSONS

SITE DESC. SAMPLE ID	MAQUADAT -----119-----		-----120-----		MAQUADAT -----119-----		-----120-----	
	PT12B CONC		PT12B TAIL		PT12B CONC		PT12B TAIL	
PH	10301L	5.8	5.1	CADMIUM $\mu\text{g/L}$	40009	<.002	<.002	
EC $\mu\text{S/cm}$	02041L	450	470	CHROMIUM $\mu\text{g/L}$	24009	<.002	<.002	
CALCIUM $\mu\text{g/L}$	20103L	48	49	COBALT $\mu\text{g/L}$	27311P	0.14	0.16	
MAGNESIUM $\mu\text{g/L}$	12102L	7.3	6.2	COPPER $\mu\text{g/L}$	29009	0.031	0.034	
SODIUM $\mu\text{g/L}$	11102L	23	25	LEAD $\mu\text{g/L}$	82211P	<.05	<.05	
POTASSIUM $\mu\text{g/L}$	19103L	3.8	4.3	MANGANESE $\mu\text{g/L}$	25009	1.79	2.07	
IRON $\mu\text{g/L}$	26304L	0.62	1.59	MOLYBDENUM $\mu\text{g/L}$	42311P	<.01	<.01	
SULPHATE $\mu\text{g/L}$	14306L	138	143	NICKEL $\mu\text{g/L}$	28311P	0.29	0.34	
CHLORIDE $\mu\text{g/L}$	17203L	36.4	34.0	SILICON $\mu\text{g/L}$	14111P	3.91	4.25	
CARBONATE $\mu\text{g/L}$	06301L	<1	<1	THORIUM $\mu\text{g/L}$		<.05	<.05	
BICARBONATE $\mu\text{g/L}$	06201L	<1	<1	URANIUM $\mu\text{g/L}$	92111L	<.2	<.2	
T ALKALINITY $\mu\text{g/L}$	10101L	<1.0	<1.0	VANADIUM $\mu\text{g/L}$	30009	<.002	<.002	
T HARDNESS $\mu\text{g/L}$	10602L	150	148	ZINC $\mu\text{g/L}$	30311P	0.107	0.126	
T DIS SOLIDS $\mu\text{g/L}$	00203L	258	263	REL DEN.		1.01	1.00	
P ALKALINITY $\mu\text{g/L}$	10151L	<1	<1	REDOX POT.		501	312	
FLUORIDE $\mu\text{g/L}$	09105L	<0.1	<0.1	BROMIDE		<0.5	<0.5	
PHOSPHATE DRT $\mu\text{g/L}$	15256L	<0.005	<0.005					
RESIDUE FILT $\mu\text{g/L}$	10451L	300	350					
RESID NOMFILT $\mu\text{g/L}$	10401L	<1	2					
NITRATE $\mu\text{g/L}$	07301L	0.26	0.28					
NITRITE $\mu\text{g/L}$	07205P	<0.05	<0.05					
ALUMINIUM $\mu\text{g/L}$	13311P	0.20	1.62					
ARSENIC $\mu\text{g/L}$		<.2	<.2					
BARIUM $\mu\text{g/L}$	56009	0.020	0.018					

"Solids" is a calculated sum of dissolved constituents.

"Nitrate Nitrite" is expressed as Nitrogen.

"Alkalinity" is Carbonate & Bicarbonate expressed as Calcium Carbonate.

"Conductivity" (E.C.) is in microsiemens/cm and is a measure of Solids.

"Hardness" is Calcium and Magnesium expressed as Calcium Carbonate.

ANALYST

E. Callin

APPENDIX III

